N69 02010

BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

SUBJECT: Trip Report - Discuss Stage and One-Half Launch System Studies at Lockheed - Case 105-3

DATE: February 4, 1969

FROM: D. E. Cassidy
C. C. Ong

ABSTRACT

Lockheed Missiles and Space Division is studying the stage and one-half integral launch and reentry vehicle. They believe that such a system can be delivered by CY 1975 for a development cost of about 1.7 billion dollars. This system, they feel, could be operated for 2.5 million dollars per launch and deliver over 20,000 pounds of discretionary payload to orbit.

The low operational cost is possible, however, only if aircraft like operations can be adapted. Lockheed has been concentrating on developing a vehicle design which has this potential and is most optimistic about being able to achieve it.

A new material, LI-1500, being developed for the outer surface heat protection, over an aluminum "aircraft" substructure, looks very promising for low cost and long life. Low cost rolled aluminum sheet tanks (glued and butt welded) also look promising for the expendable drop tanks.

(NASA-CR-103908) TRIP REPORT - DISCUSS STAGE AND ONE-HALF LAUNCH SYSTEM STUDIES AT LOCKHEED (Bellcomm, Inc.) 13 p

N79-72110

Unclas
00/15 11451

B69 02010

BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

SUBJECT: Trip Report - Discuss Stage and One-Half Launch System Studies at Lockheed - Case 105-3

DATE: February 4, 1969

FROM: D. E. Cassidy
C. C. Ong

MEMORANDUM FOR FILE

Discussions were held with personnel of the Lockheed Missiles and Space Division, Sunnyvale, California on January 7, 1969. The purpose was to review the work being performed on reusable spacecraft and stage and one-half launch systems. Lockheed participants were Jim Dodd, Grover L. Alexander, Fred Guard, Robert L. Hommitt, W. Vaughn and Max Hunter. Bellcomm participants were C. C. Ong and D. E. Cassidy.

Introduction

The next generation of earth launch and reentry systems should be relatively inexpensive to operate, hopefully an order of magnitude less than at present. To achieve lower cost, however, radical changes in the way space vehicles are built, tested, and operated will be necessary. This is the driving force behind the concept of the stage and one-half integral launch vehicle (SOH) which, for routine launch and recovery, takes on characteristics far closer to aircraft type operations than the traditional spacecraft. An example is the Lockheed operational concept illustrated in Figure 1. Lockheed as well as other aerospace companies is studying the SOH concept as an advanced launch and reentry system.* Lockheed was previously using the name Star Clipper for their system but is now referring to it as the Space Shuttle.

Although the skeptic can have a field day questioning these concepts and departures, particularly with traditional spacecraft experience in mind, he can also ponder the question: "what should be so different about routine spacecraft operations and aircraft operations?" This question (or stated another way, "how can spacecraft be made and operated like aircraft?") will require considerably more study before it can be answered properly. Some of the key technical issues as viewed by Lockheed are presented in Figure 2.

---

*Trip Report - Discussion of Integral Launch Vehicle/Spacecraft Studies at McDonnell Douglas, St. Louis, Bellcomm Memo for File, D. E. Cassidy, November 25, 1968.

Lockheed's main thrust to date has been directed toward the vehicle design, analyses of structural and heat shield materials, and the shuttle core vehicle aerodynamic performance. The boost engine system is based on the specifications for the Pratt and Whitney high pressure engine. The methods that Lockheed is suggesting for performing systems testing, vehicle qualification and operational checkout procedures, on the other hand, remain essentially conceptual. More work remains to be done to demonstrate that the core vehicle performance and turn-around capability can be made similar to a high performance aircraft as Lockheed claims. One approach that could develop high confidence in systems performance would be to qualify the vehicle through progressive flight testing as illustrated in Figure 3.

The cost estimates for operating the Space Shuttle system are a direct reflection of the aircraft like philosophy. Lockheed figures a Space Shuttle system could put over 20,000 pounds of discretionary payload into orbit for less than 2.5 million dollars per launch. Of the 2.5 million, one million is for refurbishment and support (including the expendable tanks and propellant), $200,000 is for mission operations, $500,000 for launch operations and $700,000 is used to amortize the vehicle unit cost over 50 flights. The development cost to achieve this system according to Lockheed would be about 1.7 billion dollars.* In addition, they claim that the system could be delivered by CY 1975 if a program development plan (Phase B) is initiated in mid CY 1969.

The paragraphs that follow discuss in some detail Lockheed's concepts for the heat protection system and structure (major items influencing refurbishment costs), and the low cost drop tank concept (the major expendable item). Lockheed holds high hopes for LI-1500, (new material developed in their shop) as a low cost, low maintenance, reusable radiative heat protection material (for the core vehicle outer surfaces).

---

*McDonnell Douglas is not as optimistic as Lockheed in achieving low core vehicle refurbishment costs, airframe costs, number of reuses and drop tank costs. MAC-DAC claims a 15 million dollar operational cost and a 3.7 billion dollar development cost. In contrast, NAR reflecting traditional S/C philosophy, presently estimates over 25 million collar operational costs and a development cost of over 4.5 billion dollars.

LI-1500 Material

LI-1500 (light weight insulation with a density of 15 lbs/ft^3) is a rigid insulation material developed primarily for reusable high lifting reentry vehicle application where the heating rate is 40 to 50 BTU/ft^2-sec or less. LI-1500 is made of colloidal silica with randomly oriented silica fiber reinforcement, and is inorganically bonded and cured at a temperature in excess of 2500°F but less than the 3100°F melting temperature.

LI-1500 has been under continuous modification and improvement at Lockheed. The latest version has a unit weight of 11 lbs/ft^3 and, for multi-reuse applications, is presently limited to a maximum surface temperature of 2500°F. Earlier tests on the linear thermal expansion of LI-1500 showed that the material exhibited an expansion over the temperature range between 70 and 1400°F and then a shrinkage as the temperature increased further. The coefficient of thermal expansion prior to material shrinkage was approximately 3×10^{-7} in/in F°. Recent tests of the material under heat pulses over a 50-minute time span, representing a typical reentry thermal environment with a peak temperature of 2300°F, showed that after 10 cycles of heating the material exhibited no shrinkage or other damages. Acoustic tests did not result in failure until a noise level of 168 db was reached, which exceeds the expected maximum level of 165 db.

A coating material, chromium-oxide, has been developed to provide a hard layer on the surface and to increase the surface emissivity. The room temperature tensile strength of LI-1500 is around 100 psi.

It is felt that for heat shield applications, LI-1500 has potential merit in terms of reduced unit costs, simplified structure and low refurbishment cost. Continued development may lead to the required confidence in performance and cost-saving for spacecraft applications. Present cost estimates for LI-1500 are $40 to $50 per pound. For a typical passive system the average cost per square foot of LI-1500 would be about $150 to $300/ft^2. Present estimates of coated refractory metal heat shields vary from two to over ten times this amount.

Additional LI-1500 Development

Lockheed research and development efforts on the LI-1500 in the immediate future are:

1. The emissivity of both coated and uncoated LI-1500 will be tested at Air Force Materials Laboratories, Wright-Patterson Air Force Base;

2. Bonding of LI-1500 to the substrate and some mechanical fastening methods will be investigated for the purposes of finding a simple way for heat shield replacement; and

3. Large panels and curved panels will be tested.

Further work will be conducted on the coating materials, manufacturing processes, weight and property improvement. Inspection and refurbishment methods are also planned pending in-house and government fundings.

Thermal Protection System

The structural design of the spacecraft resembles the conventional aircraft construction with the exception of a heat shield exterior to the airframe shell. The substrate temperature was kept below 150°F; this permits use of aluminum for the load-carrying structure.

Lockheed trade studies of the thermal protection system have centered to a large extent on the probable success of the LI-1500 material development. A study of five structural concepts for heat shield design was made for a spacecraft configuration with a hypersonic L/D of 2, as shown in Figure 4. These concepts, illustrated in Figure 5, included three variations of passive cooling (LI-1500, refractory metal, and ablative heat shield), as well as LI-1500 and refractory heat shields with active cooling tubes. The passive cooling system using LI-1500 was favored over the active cooling system because it was more reliable and less costly.

One of the difficulties in applying LI-1500 material for the passive heat shield was that the temperature of the substrate continues to rise after the spacecraft touches down. The temperature in the main structure could be kept below 150°F at all times only by using a very thick plank of LI-1500 (more than 5 inches). However, it was found that substantial weight savings (reduced thickness) could be achieved by applying ram cooling during the subsonic flight before touchdown and then applying ground cooling by connecting the spacecraft to a ground power source immediately after the touchdown. With this technique, the LI-1500 heat shield could be much lighter than the refractory heat shield (coated columbium) and not require an active on-board cooling system.

More test data are required to define the properties and the performance of LI-1500 to the confidence level of coated refractory metals. Lockheed engineers suggest, however, that if the development of LI-1500 does not reach its maturity in time for application, a coated refractory metal or an ablative heat shield could be relied upon. The penalties imposed with this approach require more detailed analyses.

Drop Tank

The drop tank of Star Clipper is a pressure stabilized shell with 2219-T87 aluminum tank walls using exterior insulation of polyurethane and a layer of light weight foam, Figure 6. The cost of these tanks is estimated at $34/lb for the 200th production unit assuming 90% learning in production.

The low cost, to some extent, is dependent on feasibility of the Lockheed joining technique. In this method, the tank wall sheets are backed up with a doubler plate at the butt joints and resistant spot and seam welded. Bonding agent is applied between the doubler plate and the sheets prior to welding. By applying this technique tank walls could be made of rolled aluminum sheets, thus eliminating the costly work of machine milling the material from a thick plate.

D. E. Cassidy

D. E. Cassidy

C. C. Ong

C. C. Ong

1013-$\frac{\text{DEC}}{\text{CCO}}$-nma

Attachments
  Figures 1 - 6

OPERATIONAL CONCEPT

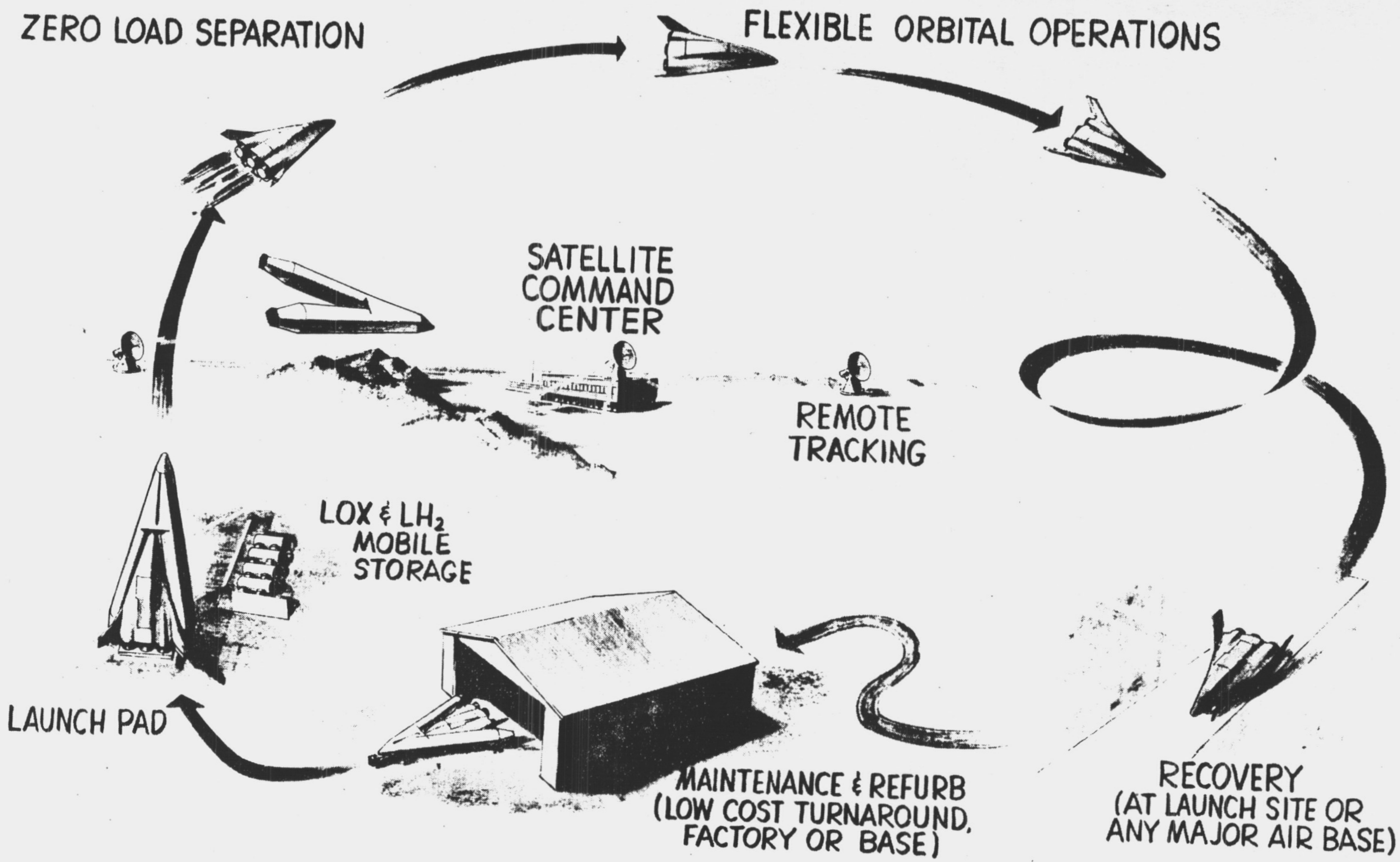


FIG. 1

KEY TECHNICAL ISSUES

- ENGINES
- REUSABLE THERMAL PROTECTION
- LONG LIFE SUBSYSTEMS
- MODULAR PAYLOADS
- LOW COST DROP TANKS
- SHAPE DERIVATION
- PREDICTABLE RECOVERY
- ON-BOARD CHECKOUT SUB-SYSTEM
- CENTRAL C/C
- INTEGRATED FLT CONTROL AVIONICS

FIG. 2

SYSTEM DEVELOPMENT PLANNING

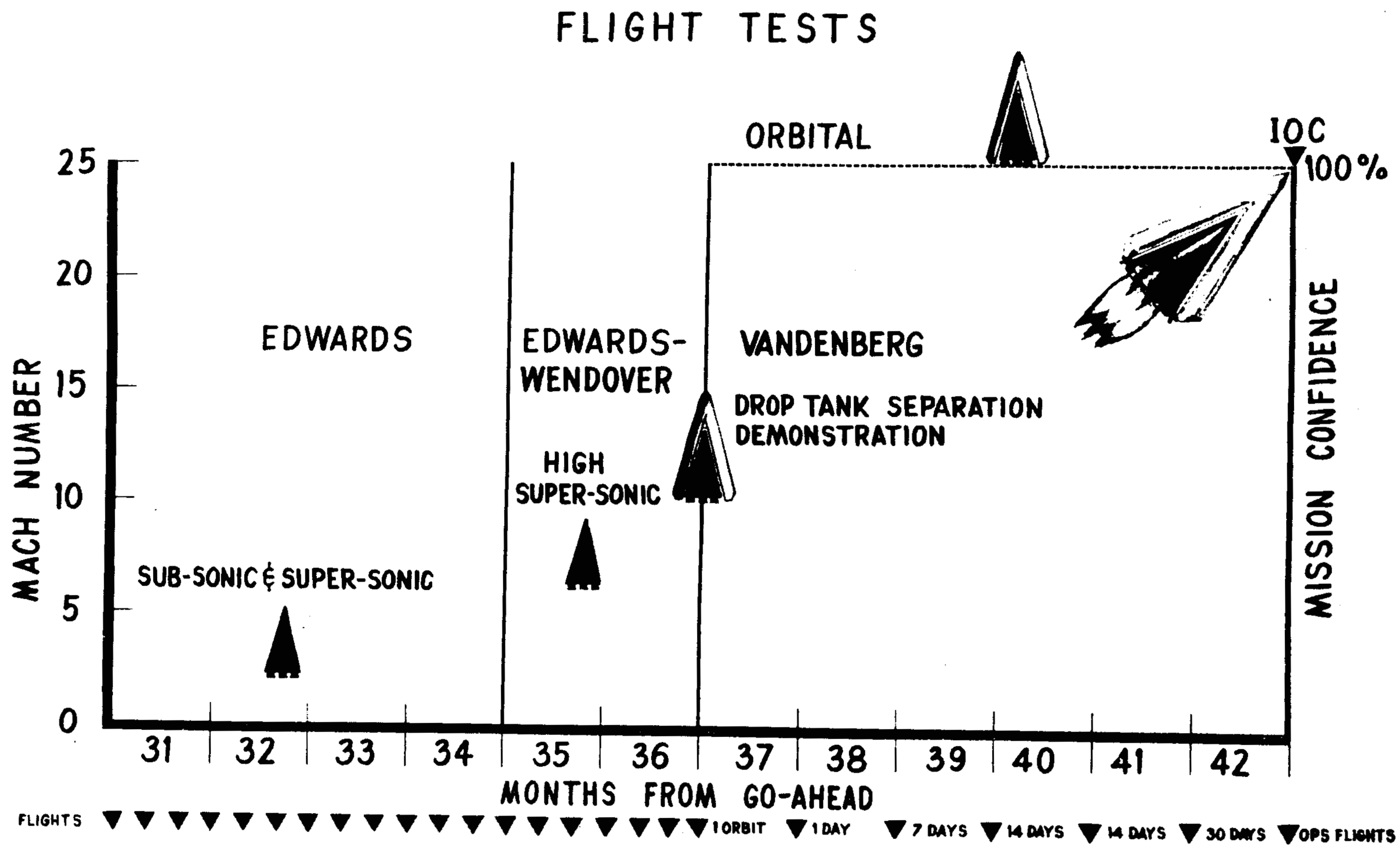


FIG. 3

MAJOR STRUCTURAL COMPONENTS

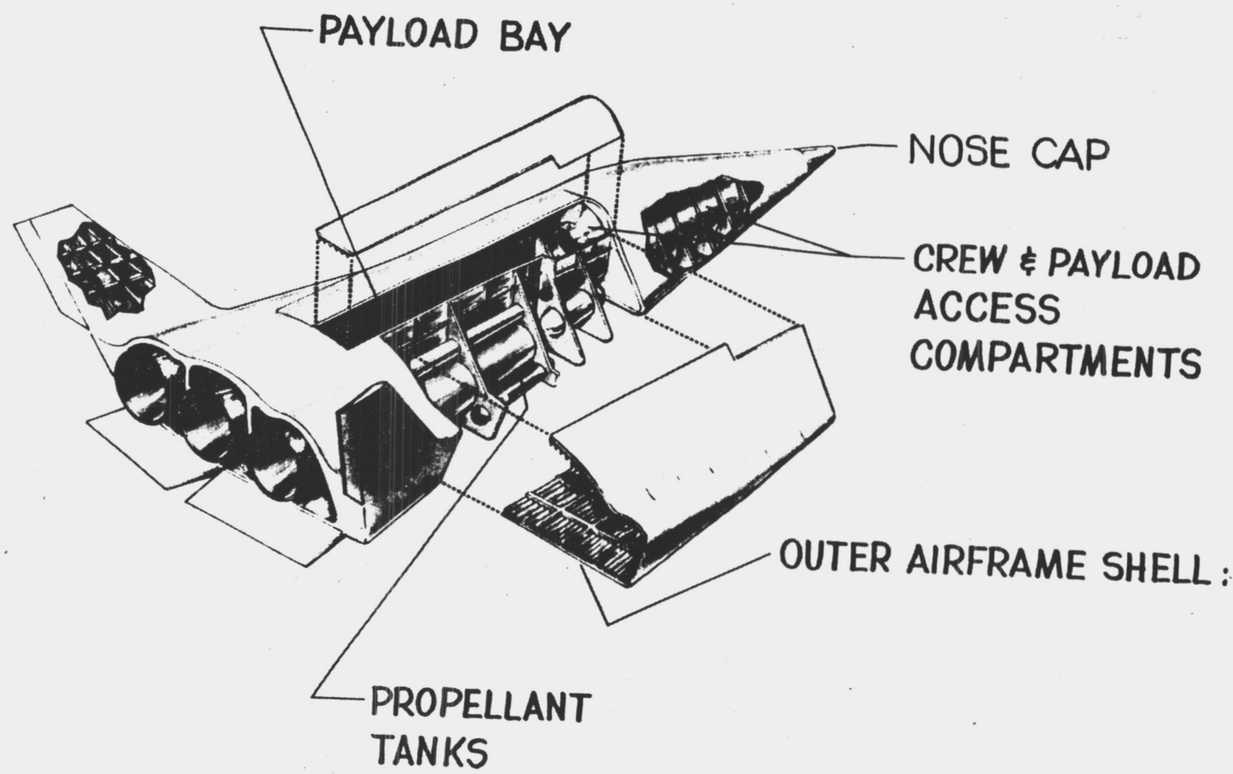


FIG. 4

PASSIVE & ACTIVE T.P.S. FOR L/D = 2

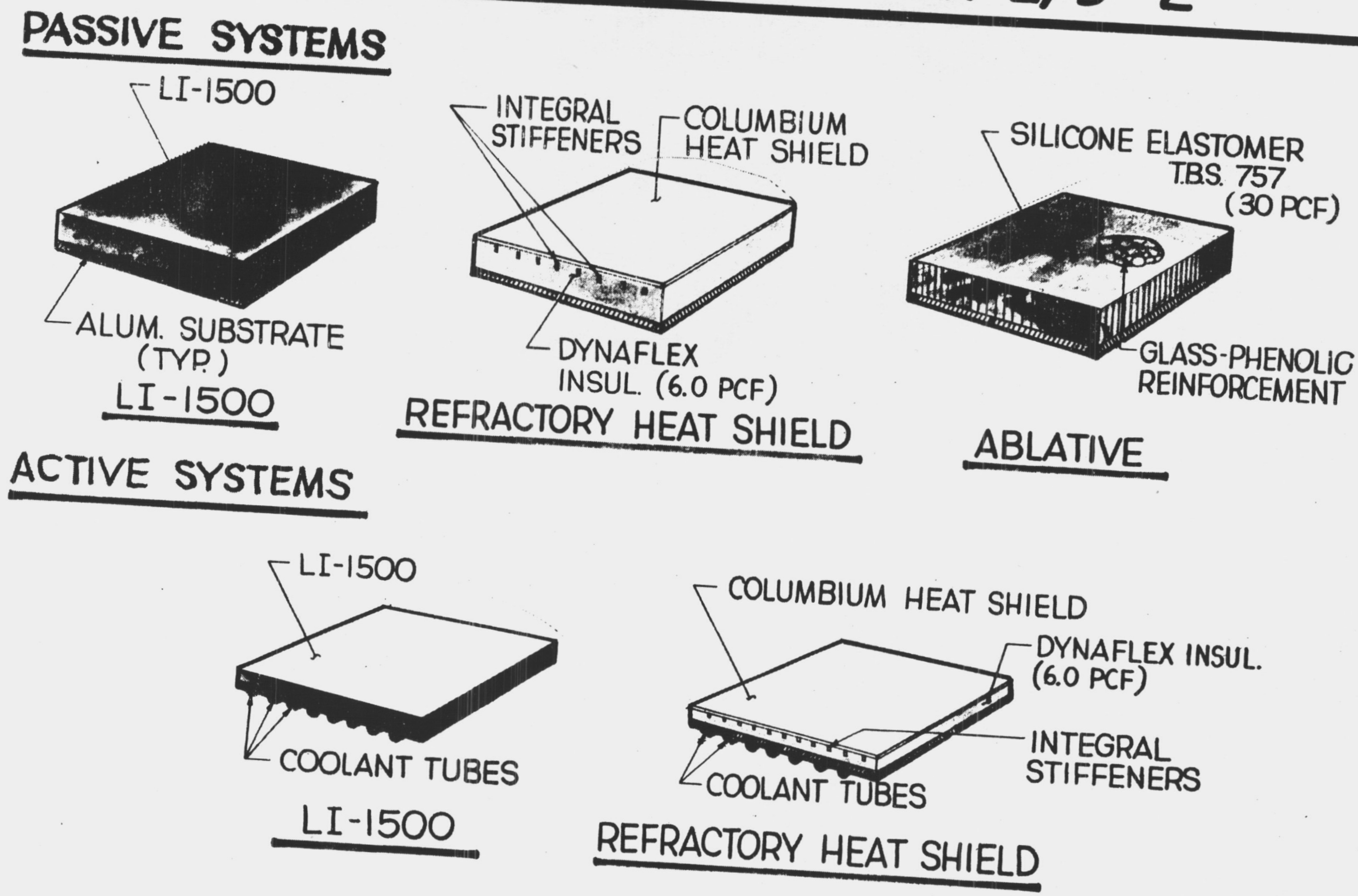
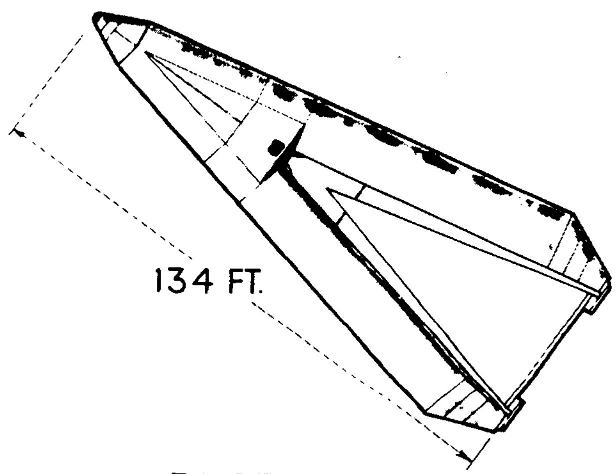
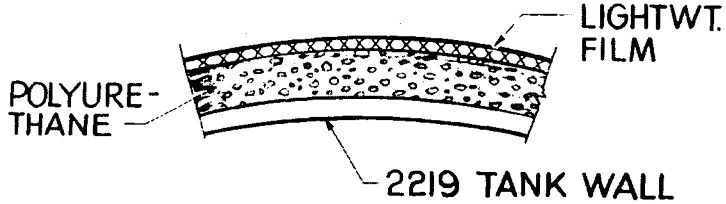


FIG. 5

DROP TANK FABRICATION & COST



DROP TANK FABRICATION



TYP. SECTION LH_2 TANK

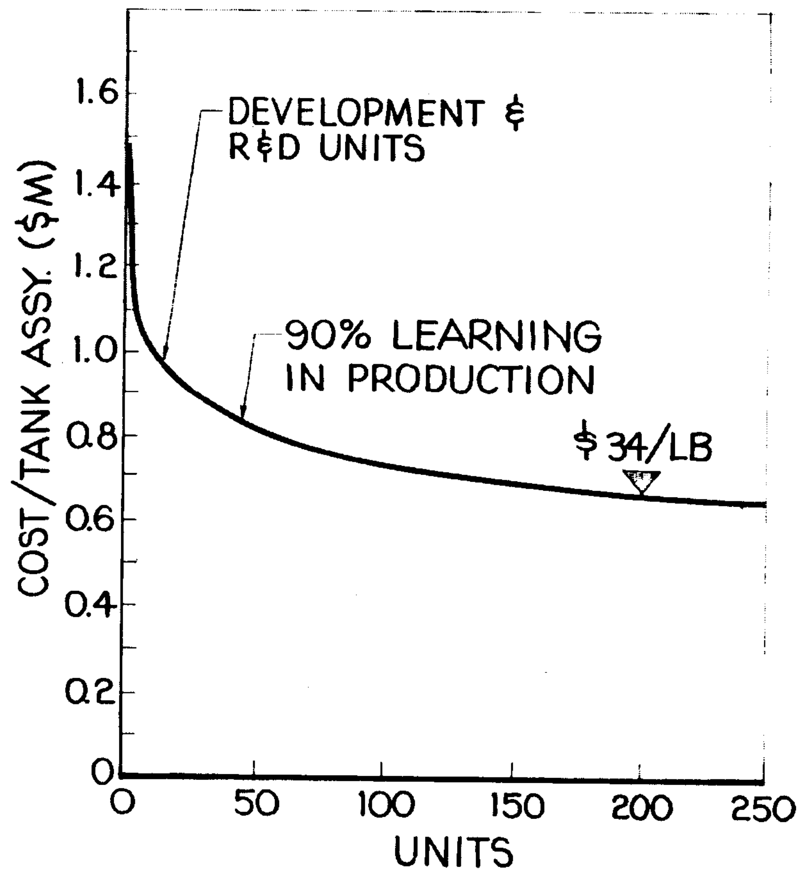


FIG. 6